THE ECONOMIC EFFICIENCY OF FINNISH REGIONS 1988-1999. AN APPLICATION OF THE DEA METHOD*

Ilkka Susiluoto
City of Helsinki Urban Facts
P.O.Box 5530 (Unioninkatu 28 B)
00099 City of Helsinki, Finland
ilkka.susiluoto@hel.fi

Heikki A. Loikkanen
Department of Economics
FIN-00014 University of Helsinki, Finland
heikki.loikkanen@helsinki.fi

Abstract: Private sector economic efficiency of 83 Finnish labour market areas in 1988-1999 is investigated. Data Envelopment Analysis (DEA), a non-parametric linear programming method is employed, calculating a best practise production frontier for the decision making units, and comparing the various DMUs with this frontier. Inputs of the study include capital stock, employment by education level, years of schooling and volume of local public sector activity. Outputs are regional value added and personal direct real income from employment. According to the results, the largest regions rate above average in DEA-efficiency, and several small, specialised regions rate near the top. The more efficient regions tend to be in the southern part of the country. The most inefficient regions are small, usually peripherally located, and their economic development has been weak. DEA-efficiency correlates with employment growth, and there is a fair amount of temporal stability in the results. Regional efficiency differences seem to have increased during the study period.

* Paper prepared for the 41st Congress of the European Regional Science Association, Zagreb, Croatia, 29.8. - 1.9.2001

1. Introduction

The purpose of this paper is to present some results concerning economic performance of Finnish regions. More specifically, we study inter-regional and inter-temporal differences in efficiency (or productivity). Our data consists of regional input and output variables concerning 83 NUTS 4-level regions in Finland during the period 1988-1999. We apply non-parametric programming techniques by using Data Envelopment Analysis and Malmquist productivity indices. These methods make it possible to evaluate efficiency differences at each point of time and decompose efficiency growth into changes in technical efficiency over time (catching up) and shifts in "best-practice" technology over time (technical change).

Empirically the period 1988-99 is very exceptional and interesting in Finnish economic history. In the end of 1980s favourable international economic developments and financial deregulation lead to a boom which was followed by a deep crisis. Unfavourable international developments, fall of exports to the former Soviet Union, domestic currency and bank crises, and pursued economic policies lead to a cumulative decline of GDP of more than 10 per cent in 1991-94. Unemployment, which had been below 5 per cent in the end years of 1980s, sky rocketed to 17 per cent. From 1995 on economic growth has been exceptionally fast and the structure of the economy has changed as IT industries have been the fastest growing sectors. Despite favourable developments unemployment has remained at high level and also regionally recent growth has been less evenly distributed than earlier. Concentration of economic activity and population to urban centres has been a stylised fact for long, but now the process seems to be even more selective. Fewer urban areas than earlier are attracting new investment and gaining from net migration. We want to shed light on these developments by studying regionally the relation between value added of private non-residential sector and/or taxable income, and input factors including capital stock, labour force, regional knowledge base and volume of public sector activity.

In the next section we describe briefly the main features of the Data Envelopment Analysis method. In section 3, data sources, as well as input and output variables are introduced. In this connection we also present the models to be employed. In section 4 we present some empirical results concerning efficiency differences across Finnish regions. Section 5 offers some conclusions.

2. The Data Envelopment Analysis method

Data Envelopment Analysis (DEA), our non-parametric linear programming method of measuring (in)efficiency is fundamentally based on the work by Farrell (1957) which was further elaborated by Charnes et al. (1978) and Banker et al. (1984). This approach (see e.g. Färe et al.1985) has been widely used in empirical efficiency (or productivity) analysis especially in cases where the units (DMUs) use multiple inputs to produce multiple outputs, and there are problems in defining weights and/or specifying functional forms to be employed in analysis. As DEA does not require input or output prices in determining empirical efficiency frontiers based on best practise technology and related measures of inefficiency, it has become especially popular in the study of public sector. These applications include efficiency studies concerning e.g. schools, hospitals and theatres, also private sector applications have been numerous as can be seen e.g. from Seiford and Thrall (1990).

Unlike most applications of DEA where the DMUs considered are public sector units (like schools), private firms or plants, our analysis aims at assessing the economic efficiency of regions. In last few years several regional applications of DEA have emerged. Charnes et al. (1989) studied the economic performance of 28 China's cities in 1983 and 1984. Their city specific input variables included measures of labour, working fund and investment. Respectively, outputs included gross industrial output value, profits and taxes, and retail sales. They identify sources, and estimate amounts of inefficiencies in each city's performance, and study their returns to scale possibilities.

Chang et al. (1995) use DEA and the Malmquist productivity index approach to study the economic performance of 23 regions in Taiwan in 1983 and 1990. Tong applied DEA to investigate the changes in production efficiency of 29 Chinese provinces in two papers with somewhat different emphasis, variables and years considered (Tong 1996, 1997). Bernard and Cantner (1997) calculate the efficiency of the 21 French provinces in 1978-1989. In a recent study, Maudos, Pastor and Serrano (2000) analyse the relationship between efficiency and production structure in Spain 1964-93, and also assess efficiency from the regional convergence point of view.

Regional aspects are present also in several DEA studies, which concern agricultural productivity. Weaver (1984) studied agriculture in the U.S. Mao ja Koo (1997) study the performance of agriculture in 29 Chinese provinces during 1984-93 applying DEA and Malmquist productivity approach. The study by Millan and Aldaz (1998) concerns agriculture in 17 Spanish provinces in 1977-88. The variables employed in regional applications of DEA range from conventional input (labour and capital) and output (value added and income type variables) to several other indicators which are related to economic resource base and regional performance.

In his article on the strengths and weaknesses of DEA in regional applications, Stolp (1990) gives five important features of the method:

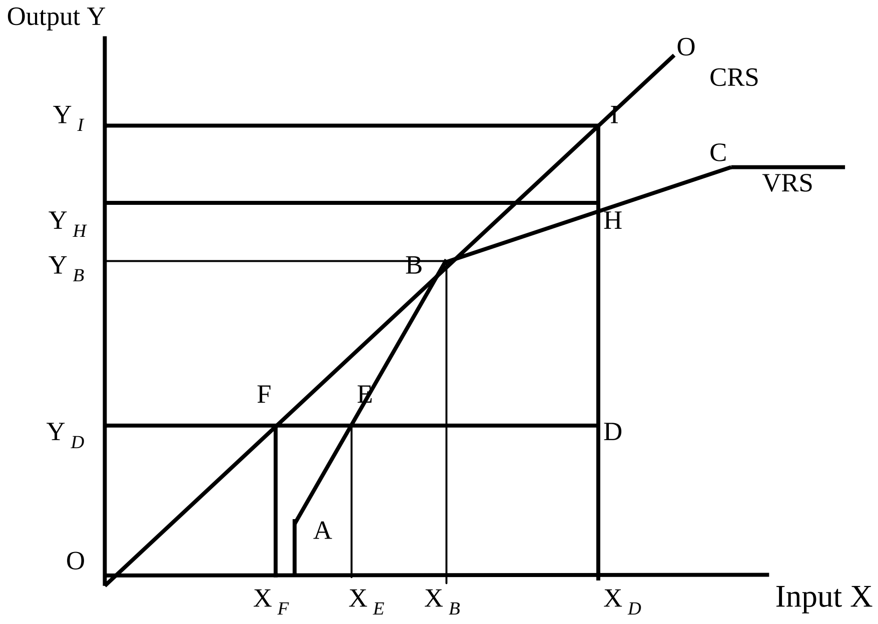
1. DEA can accommodate production relations involving multiple outputs. Its central logic is a generalisation of the simple output-to-input ratio efficiency measure.
2. DEA estimates the technical efficiency frontier. Rather than summarising the central tendency of the sample, it identifies the DMUs that represent the "best revealed practise", given weak assumptions about the monotonicity and concavity of the production process.
3. DEA identifies for each inefficient DMU a set of relatively efficient referent DMUs with a similar production structure, and estimates a relative efficiency score for each DMU.
4. DEA suggests how to reallocate inputs/outputs in order to achieve technical efficiency.
5. DEA can evaluate DMUs in terms of the local nature of returns to scale.

In the criticism about DEA, two main objections to the method have been brought up. The first concerns its nature as a "less-than-full-information statistical tool" in the sense that the location and shape of the estimated production surface is determined solely by the most efficient observations. Secondly, DEA is essentially a non-stochastic method. For a discussion on these, see Stolp (1990). To keep this paper short, we shall not present mathematically the linear programming background for DEA. We will instead graphically describe a basic case of the method.

Four decision making units are described in Figure 1 below; these are the points A, B, C and D. The DMUs use one input X to produce one output Y. Either constant returns to scale (CRS) or variable returns to scale (VRS) can be assumed for the production possibility frontier. In practical research several inputs and possibly more than one output are used, creating a multidimensional situation.

Under CRS, the most efficient unit is B, for which the tangent of the angle measured from the origin (output/input) is greatest (Y_B / X_B). Accordingly, the efficiency frontier under CRS is the line OO. Compared with B, points A, C and D are clearly inefficient. Point D for example uses more of the input (X_D) to produce less of the output (Y_D) than point B. In order to be efficient, only X_F should be used to produce Y_D, or alternatively Y_I should be produced with input use X_D. From this we get X_F / X_D as the relative efficiency of D in the input direction; in the output direction the efficiency score is Y_D / Y_I. Under CRS these two ratios are equal, or $(X_F / X_D) = (Y_D / Y_I)$.

Figure 1. Efficiency of decision making units in DEA, basic case



Under VRS the efficiency frontier passes through the points A, B and C. Consequently the relative efficiency of D is X_E/X_D in the input direction and Y_D/Y_H in the output direction, these ratios being generally unequal. In VRS efficiency can be further decomposed into scale efficiency and technical efficiency. Scale efficiency relates the size of the DMU to optimal size; in the input direction it is given by the ratio (efficient input use under CRS)/(efficient input use under VRS), or X_F/X_E in figure 1. Similarly, scale efficiency in the output direction is Y_H/Y_I. This efficiency loss is due to the inoptimal size of the DMU. The rest of the inefficiency of D is

technical inefficiency, measured by X_E/X_D in the input direction, or Y_D/Y_H in the output direction.

Finally, the change in total factor productivity of each DMU can be calculated in DEA, using the Malmquist index approach. This change can be further decomposed into the change in the relative position of the DMU with respect to the efficiency frontier (PPF), and to the movement of PPF itself. For this, see Cooper, Seiford and Tone (2000).

This article confines to some of our basic results on DEA efficiency, omitting the Malmquist productivity indexes, and assuming constant returns to scale throughout.

3. Data and models

Real value added in the business sector, published by Statistics Finland, was used as the main output variable. Public sector, non-profit organisations and the residential sector were excluded. Direct real income from private production was used as another output measure, consisting of wages, income from business, trade and profession, and agriculture. Pensions, income originating in the public sector and capital income were excluded.

Differences in regional consumption price levels were taken into account. Consequently the figures describe real regional purchasing power of the income earned, giving a supplementary welfare view to the analysis.

On the input side business sector real capital stock was used as a main variable together with the number of employed. Regional capital stock was separately constructed for the study; this is a crucial resource variable often missing in regional economic research. The number of employed was obtained from regional employment statistics, and it was divided into skilled labour with at least a lower college degree and unskilled labour. Sum of years of education of the population was used as an input measure of knowledge base of the region, supplementing the division of employment into skilled and unskilled labour. As a final input factor, regional value added of the public sector was used.

Outside the proper inputs, domestic economic accessibility of the regions was seen as a potential background factor for efficiency. Consequently an accessibility measure was calculated, weighing for each region the road distances to all other regions by the value added of the destination regions.

Five DEA models were constructed, ranging from a basic one output – two inputs system (model 1 below) traditionally used in production function studies to a system with two outputs and four inputs (model 5). These models form a succession in two directions, namely increasing the number of inputs and varying the outputs. Model 5 in particular with its two outputs demonstrates the possibilities of the DEA method, compared to ordinary parametric production function analysis.

As a result of applying DEA we get efficiency scores which range from 1 (or 100 per cent) for efficient units forming the production possibility frontier (PPF) each year to values lower than 1 indicating the degree of inefficiency. Due to problems in data availability, only models 1, 2 and 3 could be applied for 1998-99.

Table 1: Five DEA models for the calculation of regional production efficiency in Finland

Outputs	Inputs
1. Value added	Capital stock; employment
2. Value added	Construction capital; machinery and equipment; skilled labour; unskilled labour
3. Value added	Capital stock; employment; education level of inhabitants; public sector value added
4. Direct income from production	Capital stock; employment; education level of inhabitants; public sector value added
5. Value added; direct income from production	Construction capital; machinery and equipment; skilled labour; unskilled labour

The five models give somewhat varying efficiency scores for the individual regions. The correlation coefficients between the results of the model pairs are however always positive, averaging at +0.586. Correlation is highest between models 1 and 3 and lowest between models 2 and 4 (table 2); this is not surprising considering the variables that are present in the different models.

Table 2: Average correlation coefficients of regional efficiencies between the five models.

Model	1	2	3	4 (-88-97)	5 (-88-97)
1	1				
2	+0,661	1			
3	+0,936	+0,622	1		
4 (1988-97)	+0,627	+0,200	+0,692	1	
5 (1988-97)	+0,535	+0,666	+0,456	+0,469	1
Average with respect to others	+0,690	+0,537	+0,677	+0,497	+0,532

Finally, single efficiency numbers for each region and each year were obtained by taking averages over the five models.

4. Results concerning high and low performing regions

In this paper a general picture of the results is presented. We ask what common features can be found among the results of the experiments. Some short observations on the following questions are presented:

-Which regions perform systematically above or below average? Can regions be found which are more or less fully efficient in DEA terms?
-How does efficiency or inefficiency relate to the size, location and economic performance of regions?

Relative ratings of the regions were obtained by calculating averages of the DEA scores for the twelve years and five models. Table 2 contains a list of the top regions. As to Malmquist productivity indices we merely note that the average annual increase in total factor productivity was +0.8 per cent.

Table 3: Relatively efficient regions in Finland, 1988-1999

Region and rating average)	DEA index (1988-99	Population employ- ment, %	Change in total /1000 inh.	Migration balance 1999	Unempl. rate, % factor, km	Domestic distance
1 Helsinki	99,3	1085 200	+2,6	+4,9	9,6	213
2 Salo	98,3	60 500	+4,3	+3,4	9,6	250
3 Jämsä	97,7	29 300	-15,4	-1,0	18,0	230
4 Äänekoski	93,8	24 500	-12,9	-2,3	18,3	270
5 Imatra	92,9	44 100	-21,9	-7,3	19,0	315
6 Tampere	92,3	276 800	+2,8	+5,3	15,3	217
7 Sydösterbottens kustr.	91,9	20 600	-17,0	-4,9	8,8	329
8 Rauma	91,7	61 600	-15,2	-5,0	16,3	289
9 Koillis-Pirkanmaa	91,3	16 700	-14,3	-8,8	15,0	241
10 Oulu	91,0	156 900	+7,4	+5,4	15,6	469
All regions (median)	81,6	33 100	-17,0	-3,6	16,0	294

The list of ten most efficient regions has both intuitively appealing and surprising elements. Helsinki region, the capital region of Finland and by far the most important economic centre of the country, is at the top. This region is fully efficient in our DEA analysis (an efficiency score of 100 per cent) in 46 cases out of 56 possible. Altogether three of the ten largest regions by population (Helsinki, Tampere, Oulu) are on the top list; they all have also sizeable universities. Salo is a region in Southern Finland strongly specialised into mobile phones, and also Oulu has a strong electronics sector. The rest of the list includes rather small regions in Middle and Southern Finland specialised in pulp and paper.

Efficient regions generally tend to be somewhat larger than inefficient ones. There is a slight positive correlation between the size of a region and its rating in DEA efficiency, averaging at +0.34 (+0.30 excluding Helsinki).

Figure 2. Employment change 1998/99 - 1988/90 and efficiency 1988-99

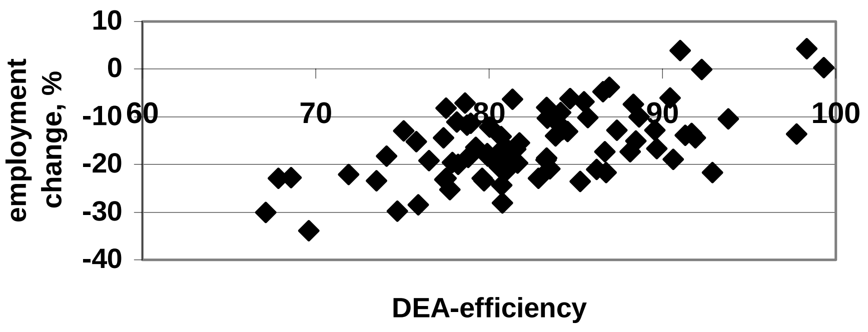


Figure 3. Migration balance 1988-99: ten most efficient and least efficient regions

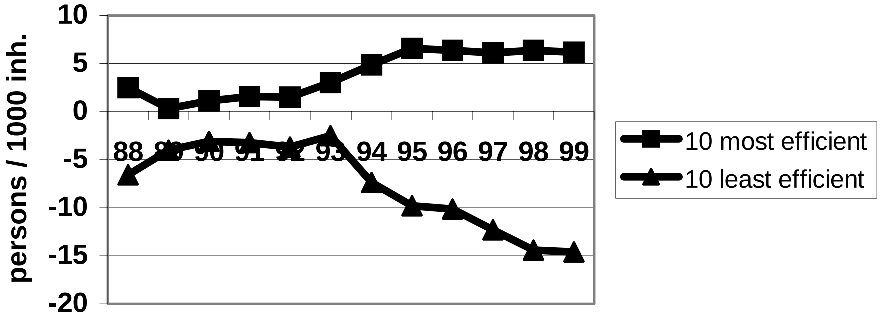


Figure 4. Economic distance factor and efficiency 1996-99

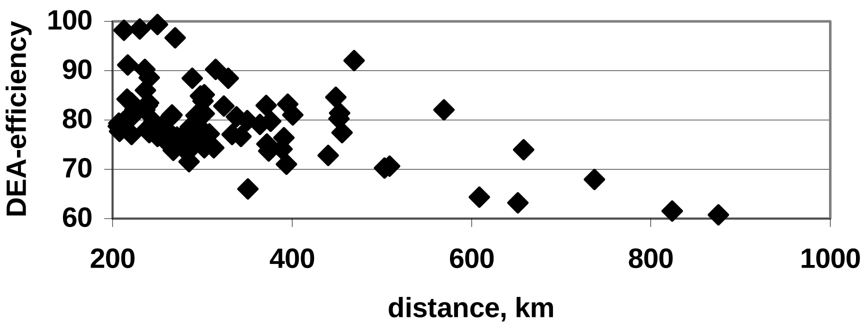


Figure 5. Annual development of regional DEA-efficiency distribution

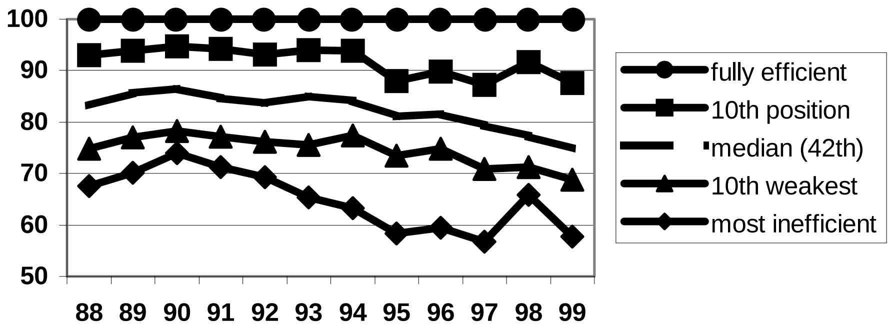
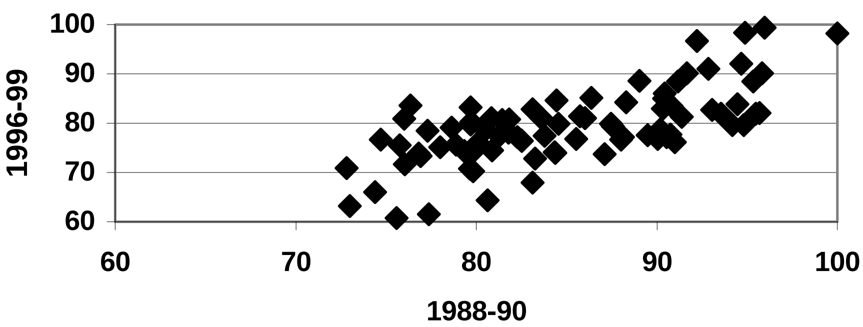


Figure 6. Changes in DEA-efficiency: regions 1988-90 and 1996-99



Changes in total employment and DEA efficiencies (figure 2) are also correlated (r =+0.60). Figure 3 shows domestic migration balances of ten most efficient and least efficient regions. A slight but increasing general positive correlation was found between DEA scores and migration balances (r=+0.23 1988-90; +0.29 1991-95; +0.45 1996-99). Inversely, the correlation between distance and efficiency was negative (figure 4), and also increasing in strength (-0.33 1988-90; -0.46 1991-95; -0.52 1996-99). Altogether, it seems that regional differences in efficiency have became somewhat larger in the study period (figure 5). On the other hand there is some temporal stability in the results, even though the relative positions of individual regions vary (figure 6, r=+0.69).

NUTS 4-level unemployment rates are available in Finland for 1991-1999. Unexpectedly, the correlation between DEA-efficiencies and unemployment rates were negative, -0.414 for efficiency 1988-99 and unemployment rate 1999, and -0.296 for (efficiency 1996-99 - efficiency 1988-90) and (unemployment rate 1999 - unemployment rate 1991).

The weakest regions are almost without exception small and without any larger economic centres. Their population varied between 7 000 and 35 000, only one being slightly above median. Value added per capita is typically low in these regions. Employment change and migration balance were below median in eight out of ten cases, and unemployment was above median in all but one region. The ten most inefficient regions tend to be peripherally located: five of them are in Northern Finland and only one is in the southern part of the country.

Table 4: Relatively inefficient regions in Finland, 1988-1999

Region and rating	DEA index (1988-99 average)	Population	Change in total employ-ment, %	Migration balance /1000 inh.	Unempl. rate, % 1999	Domestic distance factor, km
74 Ii	75,8	17 800	-13,8	-3,0	20,2	503
75 Åboland-Turunmaa	75,1	23 700	-14,8	-0,4	8,7	285
76 Koillis-Lappi	74,7	26 200	-30,1	-14,5	22,8	737
77 Saarijärvi	74,1	23 100	-18,3	-5,2	18,2	283
78 Outokumpu	73,5	14 800	-25,3	-7,0	21,6	394
79 Koillismaa	71,9	34 800	-21,4	-9,0	23,1	609
80 Kärkikunnat	69,6	7 400	-36,0	-7,8	19,6	351
81 Tunturi-Lappi	68,6	15 800	-22,1	-10,6	24,5	824
82 Pohjois-Lappi	67,8	19 700	-22,6	-7,1	24,6	875
83 Torniolaakso	67,1	11 500	-31,6	-12,5	21,8	652
All regions (median)	81,6	33 100	-17,0	-3,6	16,0	294

5. Conclusions

In this paper some results of an ongoing study were presented, concerning economic performance of Finnish regions. Non-parametric programming techniques were applied by using Data Envelopment Analysis. The approach has become popular in the study of public sectors, but recently also some regional applications have emerged. In our study, five different DEA models were applied to 83 Finnish NUTS 4-level regions in 1988-99.

Certain regularities can be found in the results. Considerable regional differences in efficiency exist; moreover these differences seem to be increasing. The more efficient regions tend to be favourably located, but also a mosaic-like geographical element can be seen. The Helsinki region obtained the highest DEA efficiency score, and the ten largest regions by population all had above average DEA efficiencies, but also several small regions specialised on pulp and paper or electronics rated high. The level of efficiency correlates positively with regional employment growth, and slightly with domestic migration balances, but negatively with unemployment rates.

The most inefficient regions are small, usually peripherally located and their economic development has been weak. There was a reasonable amount of temporal stability in the results.

REFERENCES

Banker, R.D., Charnes, A. and Cooper, W.W. (1984): Some models of estimating technical and scale inefficiencies in data envelopment analysis. Management Science, Vol. 9, No. 9, 1078-1092.

Bernard, J. - Cantner, U. (1997): French Regional Performance and Variety. A Non-Parametric Frontier Approach. Paper Presented at the 37th Congress of the European Regional Science Association, Rome.

Chang, P. - Hwang, S. - Cheng, W.(1995): Using Data Envelopment Analysis to Measure the Achievement and Change of Regional Development in Taiwan. Journal of Environmental Management, Vol. 43, 49-66.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978): Measuring the efficiency of decision making units. European Journal of Operational Research, Vol. 2, 429-444.

Charnes, A. - Cooper, W. - Li, S.(1989): Using Data Envelopment Analysis to Evaluate Efficiency in the Economic Performance of Chinese Cities. Socio-Economic Planning Sciences, Vol. 23, No. 6, 325-344.

Cooper, W. - Seiford, L. - Tone, K. (2000): Data Envelopment Analysis. Kluwer Academic Publishers.

Farrell, M.J. (1957): Measurement of Productive Efficiency. Journal of the Royal Statistical Society, Series A, 253-281.

Färe, R., Grosskopf, S. and Lovell, C.A.K. (1985): The Measurement of Efficiency of Production. Boston: Kluwer-Nijhoff.

Mao, W. - Koo, W. (1997): Productivity Growth, Technological Progress, and Efficiency Change in Chinese Agriculture after Rural Economic Reforms: A DEA Approach. China Economic Review, Vol. 8. No. 2, 157-174.

Maudos, J. – Pastor, J. – Serrano, L. (2000): Efficiency and Productive Specialisation: An Application to the Spanish Regions. Regional Studies vol. 34, 9, 829-842.

Millan, J. - Aldaz, N. (1998): Agricultural Productivity of the Spanish Regions: A Non-Parametric Malmquist Analysis. Applied Economics, Vol. 30, 875-884.

Seiford, L.M. and Thrall, R.M. (1990): Recent Developments in DEA. Journal of Econometrics, Vol. 46, 7-38.

Stolp, C. (1990): Strengths and weaknesses of data envelopment analysis: an urban and regional perspective. Computers, Environment and Urban Systems, Vol. 14, No. 2, 103-116.

Tong, C.(1997): China's Spatial Disparity within the Context of Industrial Production Efficiency: A Macro Study By the Data Envelopment Analysis (DEA) System. Asian Economic Journal, Vol. 11, No. 21, 207-217.

Tong, C. (1996): Industrial Production Efficiency and its Spatial Disparity among the TVEs of China: A DEA Analysis. Singapore Economic Review, Vol. 41, No. 1, 85-101.

Weaver, R.(1983): Multiple Input, Multiple Output Production Choices and Technology in the U.S. Wheat Region. American Journal of Agricultural Economics, Vol 65, 45-56.